ORIGINAL ARTICLE

Physiological Responses and Performance Analysis Difference between Official and Simulated Karate Combat Conditions

Helmi Chaabène[*1 ABCDG], PhD; Bessem Mkaouer[2ACEG], PhD; Emerson Franchini[3ACDEG], PhD; Nafaa Souissi[4AG], PhD; Mohamed Amine Selmi[5AG], PhD; Yassine Nagra[6ADG], PhD; Karim Chamari[7EG], PhD

Authors' Affiliation:

1. Tunisian Research Laboratory ''Sport Performance Optimisation'', National Centre of Medicine and Science in Sport, Tunisia
2. Higher Institute of Sports and Physical Education, Manouba University, Tunis, Tunisia
3. Martial Arts and Combat Sports Research Group, School of Physical Education and Sport, University of Sao Paulo, Sao Paulo, Brazil; Faculté de Science du Sport, Université de Montpellier I, France
4. Biomechanics laboratory, national Institute of Orthopedics "M.T. Kassab Tunisia"
5. Research Unit « School and University Sportive Practices and Performance », High-Institute of Sports and Physical Education, Kef, University of Jendouba, Tunisia
6. Sport Performance & Health" Higher Institute of Sport and Physical Education of Ksar Said, Tunis , Tunisia
7. Research and Education Centre, Aspetar, Qatar Orthopedic and Sports Medicine Hospital, Doha, Qatar

Authors' Contribution

- **A** Concept / Design
- **B** Acquisition of Data
- **C** Data Analysis / Interpretation
- **D** Manuscript Preparation
- **E** Critical Revision of the Manuscript
- **F** Funds Collection
- **G** Approval of the Article

*** Corresponding Author;**

Address: Research Unit, Analysis and Evaluation of factors affecting the sport performance, Higher Institute of Sports and Physical Education, Ksar said, Tunisia

E-mail: chaabanehelmi@hotmail.fr

Received: *Mar 05, 2013*
Accepted: *Sep 08, 2013*
Available Online: *Sep 20, 2013*

Abstract

Purpose: **This study aimed to compare physiological responses and time-motion analysis between official and simulated karate combat.**

Methods: **Ten high-level karatekas participated in this study, which included official and simulated karate combat.**

Results: **Karatekas used more upper-limb attack techniques during official combat compared to simulated ones (6±3 vs 3±1; *P*=0.05, respectively). For official and simulated karate matches, the numbers of high-intensity actions (i.e. offensive and defensive fighting activity) were 14±6 and 18±5, respectively (*P*>0.05), lasting from <1s to 5s each. Total fighting activity phase was lower during official compared to simulated matches (21.0±8.2s vs 30.4±9.9s, *P*<0.01, respectively). Effort (10.0±2.8s) to rest (11.9±2.7s) ratio (E:R) was 1:1 and high-intensity actions (1.6±0.3s) to rest (11.9±2.7s) ratio was higher than 1:7 during simulated combat. During official karate match, the activity and rest duration were 10.0±3.4s and 16.2±4.1s, respectively (E:R ratio 1:1.5), while high-intensity actions were 1.5±0.3s, resulting in an E:R ratio of 1:11. Blood lactate concentration was higher during official (11.14±1.82 mmol.l^{-1}) compared to simulated karate combat (7.80±2.66 mmol.l^{-1}) (*P*<0.05). Subjective perceived exertion differed significantly between official and simulated combat (14±2 *vs.* 12±2; *P*<0.05, respectively). The majority of karatekas' perceived exertion was higher in the lower limb muscle groups irrespective of the karate combat condition.**

Conclusion: **Official and simulated matches differ considerably, therefore coaches should create new strategies during training sessions to achieve the same effort and pause profile of competitive matches and/or that athletes should be submitted to frequent competitions to adapt themselves to the profile of this event.**

Key Words: Karate; Combat Sport; Time-motion Analysis; Physiological Responses

Asian Journal of Sports Medicine, Volume 5 (Number 1), March 2014, Pages: 21-29

INTRODUCTION

Since the development of tournament competitions at national and international level, karate has gained growing popularity [1,2]. Additionally, the first scientific article dealing with karate was published in 1966 [3]. Since then, more attention has been directed towards the science of karate. It has been established that karate kumite is of intermittent nature requiring the development of both aerobic and anaerobic alactic energy systems [4]. In this context, it has to be pointed out that data about karate's physiological responses are relatively limited and information concerning karate performance analysis is very scarce. To the authors' knowledge, there are only two scientific studies dealing with karate match analysis [5,6]. Beneke et al [5] reported that the average effort periods during karate match simulation were ~18s, while the recovery interval was of ~9s (i.e. effort to- rest-ratio of 2:1). Iide et al [6] established that the duration of the shortest and longest offensive and/or defensive techniques during simulated karate combat were 0.3s and 1.8s, respectively. Matsushigue et al [7] established, during official taekwondo combat which is a striking combat sport such as karate, that the mean effort time (8±2s) did not differ from the break time (8±3s) (i.e. 1:1 effort-pause ratio). More specifically, Bridge et al [8] recently reported that during the 2005 World Taekwondo Championships the fighting time was 1.7±0.3s, the preparatory time was 6.4±2.1s, the non-preparatory time was 3.0±0.6s, and referee stoppage time was 2.8±0.9s, resulting in an average fighting to non-fighting ratio of 1:6. Santos et al [9] reported mean attack times of 1.3±0.4s, stepping periods of 9.2±3.9s, and pause periods of 6.0±3.9s during 2007 World Taekwondo Championship and 2008 Olympic taekwondo competition matches, resulting in 2:1 effort-pause ratio and 1:15 attack-total time ratio. However, investigations dealing with performance analysis during official karate combat are missing.

Blood lactate responses have been widely used in different kinds of striking combat sport as in taekwondo [7,10], kung-fu [11], Muay Thai [12] and boxing [13] fight simulations. In addition to using the rating of perceived exertion (RPE) which has been recently considered as a valid tool for quantifying karate's training session [14], perceived exertion in a specific muscle group has been used too (i.e. local RPE) [15]. Authors reported that the understanding of the specific muscle groups involved during the match can provide valuable information concerning the need for a specific conditioning program [15]. Additionally, perceived recovery scale (PRS) has been used [16] to evaluate athletes' recovery process and has also been reported to be an effective subjective tool for quantifying the level of recovery between intermittent sprint activities [16]. To the author's knowledge, scientific evidence about karate combat analysis does not exist. Time-motion analysis is of major importance since it allows coaches and even athletes to identify the most appropriate ways for optimizing performance to succeed during karate combat and then programming and/or altering training accordingly [17].

Additionally, since previous studies [5, 6] dealing with karate's combat analysis and physiological responses have been conducted during a simulated karate combat environment, research treating the possible difference between official and simulated karate combat in regards to both time-motion analysis and physiological responses seems to be needed. Thus, the aim of the present investigation was to compare physiological responses and time-motion analysis between official and simulated karate combat environments in high-level karatekas. The hypothesis of the present study was that athletes would be less engaged in attack activity during official competition compared to simulated combat, however, due to the stress involved in the official competition athletes would present higher physiological and perceived strain in this condition compared to simulation condition.

METHODS AND SUBJECTS

Participants:

Ten male high-level karatekas participated in this investigation. Athletes were involved in both simulated and official (i.e. national championship) karate combat with two-weeks of interval in-between. All karatekas were black-belt level and participated regularly in national and international events (Means±SD age: 21.8±3.01 years; body mass: 75.7±8.0 kg; height: 183.7±5.9 cm; and karate experience: 13.3±2.5 years). Athletes competed in the >84 kg (n=2), <84 kg (n=2), <75 kg (n=2), <67 kg (n=3), <60 kg (n=1) weight categories. A total of twenty (i.e. ten official and ten simulated) karate combat have been analyzed. Each combat comprised athletes of similar weight category [2]. The study has been conducted within the inseason phase of the year. All athletes provided written informed consent in accordance with the declaration of Helsinki. The university ethics committee approved the study protocol.

Procedures:

Performance Analysis Measurements: After having obtained the permission from the Tunisian Karate Federation, all karate combat were taped using three Sony cameras (model DCR PC 108^E, CCD 1000000 pixels, SSC 1/4000 per second, Tokyo, Japan). In order to guarantee the covering of all the combat areas, each camera (positioned at a distance of 5-m aside from the competition area) was equipped with a fish-eye lens. A video-analysis software program (Dartfish Edition MPT34M Pro 5.5, Lausanne, Switzerland) was used to analyze the footage frame-by-frame (interval = 0.016s). Tornello et al [18] used similar procedures and a high reliability and objectivity of the system has been established.

Preparatory activity time (PT) began either following the referee's hand signal or upon termination of the fighting phase, whereas it ended either upon the referee's hand signal or when the successive fighting time started. Fighting activity (FT) was executed in the course of an exchange between the two contestants. FT began when athletes moved out from the fighting stance towards an exchange and ceased once the final execution ended. More precisely, an execution finished once the punching limb was retracted, kicking foot was returned again to the floor, and when contact between contestants ended. Stoppage activity time (ST) was started or stopped when the referee called « *hajime* », which means "to begin"or « *yame* », which means "to stop" [2]. Stoppage period (ST) included various events: General - the time required for the referee to separate contestants after an exchange; injury - period of time spent when athletes were injured; and penalty/score - represented the time required when the referees awarded a penalty and/or score to a competitor.

Any action by the karateka using only one technique, which started the sequence, was considered as an attacking phase. Combination of attack techniques has been distinguished by any action that started the sequence by the karateka using more than one technique. Whereas, counter-attack technique has been defined as any movement of the athletes to defend against the opponent's attack. High-intensity karate techniques refer to brief actions with clear vigor and muscle power. Generally, high-intensity movements refer to fighting activity, while all other actions were considered as low-intensity activity. Scores and penalties were rigorously followed during both official and simulated karate combat according to the World Karate Federation Rules [2]. Climatic conditions were as follow: 33°C and 30°C for temperature and 59% and 61% for humidity, during official and simulated karate combat, respectively.

Physiological Measurements:

Blood Lactate Concentration: Blood lactate concentrations were measured (from the fingertip using the Lactate Pro Analyzer (Arkray, Tokyo, Japan)) at rest/pre-combat and at 3-min post-combat [19] and used as an indicator of the energy contribution from anaerobic glycolysis system [5].

Heart Rate: Heart rate was recorded at 5s intervals using the Polar Team System (Team System, Polar, Kempele, Finland). The mean heart rate (HR_{mean}) was calculated as the average of the heart rate during the entire karate combat, while peak heart rate (HR_{peak}) was defined as the highest match value. It should be noted that within this study's conditions, HR responses had been successfully recorded for only 3 athletes during simulated combat and 6 athletes during official one.

General and Local Rating of Perception of Effort (RPE and LRPE): Subjective perception of effort (RPE_{6-20}) for the work performed was assessed on a scale of 6 to 20 [20] within 3-min post combat periods. Written instructions on the use of the Borg scale were read to the participants prior to the test [21] and participants were used to the method on a daily basis for at least one-month before starting the study. Recently, RPE has been revealed to be a valid tool to assess global exercise intensity during karate training sessions [14] Additionally, perceived exertion in specific muscle groups has been utilized (LRPE) [15]. After having rated the general effort, karatekas were asked to locate, on an anatomical diagram of the anterior and posterior views of the body showing the most important muscular group, the areas they perceived to experience most exertion during matches. The participants were asked how much they perceived the exertion and which muscles or muscle groups they felt more involved in the kumite's activity. This approach has been previously used by Nilsson et al [15] with Greco-Roman wrestlers in the 1998 World Championship.

Perceived Recovery Status Scale (PRS): This approach has been utilized as a parallel approach to the RPE in order to assess the level of athletes' recovery. Laurent et al [16] reported that the main advantage of this approach is to increase the chance of detecting the sign of overtraining early. The PRS scale is a 0–10, similar to that of an RPE scale, representing varying levels of an individual's level of PRS.

Athletes were asked about their recovery level just before the beginning of the combat.

Statistical analysis:

The statistical analyses were carried out using SPSS 19.0 program for Windows (SPSS, Inc., Chicago, IL, USA). Paired simple *t* test has been utilized for data comparison between karate combat conditions. Pearson correlation coefficients were used to examine association between variables. Data's normality was checked through Shapiro-Wilk test. For non-parametric data (i.e. number of techniques used, number of high-intensity actions or fighting activity, and percentage of each karate combat phases) the Wilcoxon signed-rank test was conducted. Effect size (d_z) were calculated using GPOWER software (Bonn FRG, Bonn University, Department of Psychology) [22] using the following scale for interpretation of d_z: < 0.2 [trivial]; 0.2–<0.6 [small]; 0.6–<1.2 [moderate]; 1.2–<2.0 [large]; and ≥2.0 [very large] [22]. The significance level of P<0.05 was used.

RESULTS

Karate practitioners used more frequently upper-limbs karate techniques compared to lower-limbs ones regardless of the karate combat conditions (table 1). *Kizami-zuki* (i.e. punch with forward anterior hand) represented 52.38% and 34.54% from all attack techniques used for official and simulated karate combat, respectively. From all karate techniques it represented 33.33% and 15.07% and from upper-limb attack techniques it represented 81.48% and 61.29% for official and simulated karate combat, respectively. Concerning lower-limbs karate techniques, *mawashi-geri- chudan* (i.e. circular kick to the body) represented 30% and 16.66% for official and simulated karate combat, respectively. From counter-attack techniques during official and simulated karate match, *gyaku-zuki-jodan* (i.e. punch to the head) represented 50% and 55.31%, respectively. From upper-limbs karate counter-attack techniques it represented 61.11% and 66.66% for official and simulated combat, respectively. From combination of attacks, *kisami kyaku-zuki jodan* (i.e. feint by punch with forward anterior hand followed by punch to the head) represented 53.84% and 29.11% for official and simulated karate combat, respectively. Overall, regarding attack techniques, athletes used upper-limb technique during official karate combat more frequently than during simulated ones (6±3 vs 3±1, respectively; P=0.05).

Fighting, preparatory, and stoppage activities' duration in relation to karate combat conditions are presented in Table 2. For official and simulated karate matches, the numbers of high-intensity actions were 14±6 and 18±5, respectively (P>0.05), lasting from <1s to 5s each. The number of techniques used during

Table 1: Percentage of upper and lower limb karate technique according to karate combat conditions

Variable		All Technique Mean (SD)	Attack Technique Mean (SD)	Counter attack technique Mean (SD)	Combination of attack technique Mean (SD)
Simulated condition	Percentage of upper limb	73.2 (24.4)	54.6 (28.9)	84.9 (26.6)	100 (0)
	Percentage of lower limb	26.8 (24.4)	45.4 (28.9)	15.1 (26.6)	0 (0)
Official condition	Percentage of upper limb	73.2 (19.6)	63.1 (23.7)*	82.7 (32.8)	100 (0)
	Percentage of lower limb	26.8 (19.6)	36.9 (23.7)	17.3 (32.8)	0 (0)

* Significantly different from simulated condition combat; SD: Standard Deviation

Table 2: Duration of preparatory, fighting, and stoppage activities (in seconds) in relation to karate combat conditions

Combat phases	Simulated karate combat Mean (SD)	Official karate combat Mean (SD)
Fighting activities (s)	1.6(0.3)	1.7(0.7)
Preparatory activities (s)	8.5(2.9)	9.8(4.9)
Stoppage (s)	11.5(2.7)	17.3(5.2)*

* Significantly different from simulated karate combat (*P*<0.05) ; SD: Standard Deviation

official and simulated karate combat were 13±4 and 13±6, respectively, with no significant difference between the two karate combat conditions (*P*>0.05).

Percentage of PT and FT was significantly lower during official compared to simulated combat (45.8±12.2% and 6.8±2.3% vs 55.2±9.3% and 10.4±3.3%, respectively; *P*<0.05), while percentage of ST was significantly higher during official compared to simulated combat (47.4±12.5% vs 34.4±7.5%, respectively; *P*<0.05).

Total time of fighting activity phase was 20.9±8.1s for official and 30.4±9.9s for simulated karate combat (*P*<0.05). During simulated karate combat, the t-test revealed that there was no significant difference (t= -1.16; df=18; *P*=0.25; *dz*= 0.68 [moderate]) between the duration of exercise (10.0±2.8s) and pauses (11.9±2.7s), which corresponded approximately to an effort-rest ratio (E:R) of 1:1. High-intensity actions (1.6±0.3s) to rest (11.9±2.7s) differed significantly (t= 11.70; df=18; *P*<0.0001; *dz*= 5.46 [very large]) and generated an effort-rest ratio higher than 1:7.

During official karate matches, there was a significant difference (t=-3.46; df=18; *P*=0.003; *dz*= 1.63 [large]) between the activity and rest duration (10.0±3.4s and 16.2±4.1s) respectively, which corresponded approximately to an effort-rest ratio of 1:1.5. There was also a difference between high-intensity actions (1.5±0.3s) and pauses (16.2±4.1s) (t=10.66; df=18; *P*<0.0001; *dz*=5.03 [very large]) with an effort-rest ratio of 1:11. During simulated karate condition, 75.98±14.74% of the fighting periods lasted less than 2s. Similar percentage (78.63±15.44%) was observed during the official match. A significant difference regarding time interval between high-intensity actions (TI) was found between the two karate combat conditions: TI was 16.2±4.1s for simulated and 25.7±10.2s for official karate combat (t=-3.43; df=9; *P*=0.007; *dz*=1.08 [moderate]).

Blood lactate concentration and perceptive responses are presented in table 3.

There was a significant difference in blood lactate concentration [La] recorded 3-min after the completion of the match between official and simulated karate match (t=-2.52; df=9; *P*=0.03; *dz*=1[moderate]), with higher values in the official match compared to the simulated ones.

RPE was higher during official compared to simulated karate combat (t=2.81; df=9; *P*=0.02; *dz*= 0.77[moderate]). There was no significant relationship between [La] and RPE. Concerning PRS, there was no significant difference between the two karate combat conditions (t=1.34; df=9; *P*=0.23; *dz*= 0.24 [small]). There was no significant correlation between PRS and both the number of high-intensity actions and the total time of fighting activity (*P*>0.05).

Peak heart rate (HR_{peak}) for official and simulated karate combat was 193±8 beats.min^{-1} and 192±9 beats.min^{-1}, respectively. Heart rate means (HR_{mean})

Table 3: Blood lactate and perceptive responses in relation to karate combat conditions

Combat condition	Blood lactate rest (mmol.l^{-1}) Mean (SD)	Blood lactate post (mmol.l^{-1}) Mean (SD)	RPE Mean (SD)	PRS Mean (SD)
Simulated karate combat	1.23 (0.4)	7.80 (2.7)	12 (2)	5.8 (1.3)
Official karate combat	1.83 (0.5)	11.14 (1.8)*	14 (2)*	5.2 (2.0)

RPE: rating of perceived exertion; PRS: perceived recovery status scale
*: Significantly different from simulated karate combat (*P*<0.05)

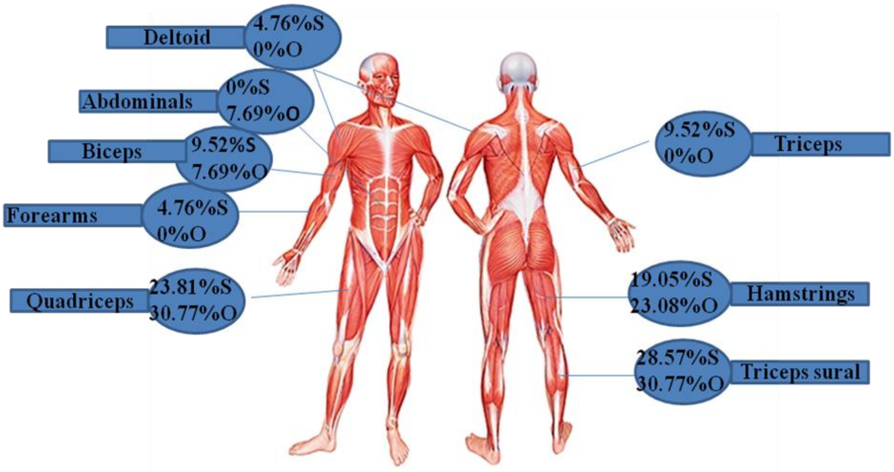

Fig. 1: Percentage of the highest local rating of perceived exertion in the different muscle groups. S: values from simulated karate combat; O: values from official karate combat.

were 177±13.43 beat.min^{-1} (91.70% HR_{peak}) for official and 175±11 beats.min^{-1} (91.14% HR_{peak}) for simulated combat.

LRPE is shown in Fig. 1. The majority of karate athletes' perceived exertion was higher in the lower-limb muscles irrespective of the karate combat condition. LRPE was pointed out by the following percentages of athletes: 30.77% and 23.81% for quadriceps, 23.08% and 19.05% for the hamstrings, and 30.77% and 28.57% for the triceps sural muscle during official and simulated karate combat, respectively, with no significant difference between the two karate combat conditions.

DISCUSSION

The aim of the present study was to analyze the difference regarding physiological responses and time-motion analysis between official and simulated karate combat conditions.

The major findings of the present study were that: a) karatekas used more upper-limb attack techniques during official combat compared to simulated one; b) the percentage duration of both pause and fighting times were higher during simulated karate combat, whereas stoppage time was longer during official matches; c) a significant difference regarding time-interval between high-intensity actions, with longer intervals during official condition compared to the simulated one; d) [La] was higher during official karate combat; e) athlete's perceived exertion was higher during official compared to simulated karate combat; and f) the majority of karatekas' perceived exertion was higher in the lower-limb muscle groups irrespective of the karate combat condition.

Within the current study, the use of upper-limb karate techniques has been revealed to be higher than lower-limbs ones either during simulated or official karate combat conditions. These findings agree with those of Koropanoski et al [24] and Laird et al [25]. These authors revealed that the upper-limb karate techniques were the most frequently used. The longer lane (i.e. trajectory) as well as the time required for the execution of lower-limb techniques compared to upper-limbs ones can explain this difference [26]. Karatekas used more upper-limb attack techniques during official compared to simulated karate combat. Percentage of occurrence of k*izami-zuki* upper-limb technique within official condition is twice as present as during simulated combat. This can be due to the fact that these athletes try to use techniques that provide more chances to score during official combat compared to simulated ones. In this context, *kizami-zuki* requires short-time for its execution added to its precision and the fact that the implementation of this technique allows the karateka to remain protected whilst attacking [17]. This probably explains why it is the most preferred technique during official conditions. Jovanovic et al [27], reported that the time necessary for performing *kizami-zuki* was 0.11s, which is less than the duration of *gyaku-zuki* which takes about 0.15s.

Data concerning lower-limb attack techniques showed that *mawashi-geri- chudan* (i.e. circular kick to the body) during simulated condition was about half the amount recorded during official combat. The short time required for the execution of this karate skill (0.177s) compared to all other lower-limb techniques [28] and, then, the large likelihood to be correctly scored through its use may also explain its predominance, particularly during official conditions.

When considering counter-attack techniques during simulated and official karate combat, *gyaku-zuki-jodan* (i.e. punch to the head) was the most used one regardless of the karate combat's condition. This finding agrees with those previously reported by Korapanovski et al [17]. These authors revealed that the percentage of using *gyaku-zuki* during combat was 64.91%, of which 34.91% applications were on the trunk (*chudan*) and 32% applied to the head (*jodan*). Overall, with respect to attack techniques, athletes used more upper-limb techniques during official karate combat than during simulated ones. The dominance of upper-limb karate techniques during official conditions may be explained by the greater chance to reach the target accurately in a short period of time, which characterizes the execution of these karate skills compared to lower-limb ones.

The high percentages of actions lasting less than 2s during simulated and official karate combat are similar to those reported by Beneke et al [5] who found 16.3±5.1 high-intensity actions lasting 1-3 s each during simulated karate combat. Similar results were also found in taekwondo matches. Bridge et al [8] reported that the percentage of actions which lasted less than 2s during official taekwondo sparring was 72±16%. The percentage of each karate combat phase differed significantly between simulated and official combat. Pause time was significantly less present in simulated compared to official combat. For fighting time, the total time recorded was higher during simulated compared to official matches. This means that karate athletes were slightly less engaged in fighting time in this condition and then more cautioun was observed during official fights compared to simulated ones. This is supported by the higher time interval during official compared to simulated combat. In the study of Iide et al [6], the mean total time relative to fighting actions was 19.4±5.5s during 3-min of karate combat simulation. In the present investigation, the mean total time of FT was higher (30.4±9.9s) during simulated combat, whereas it was similar (20.9±8.1s) to the Iide et al [6] study during official karate combat.

The activity (18±6s) to pause (9±6s) ratio in the study of Beneke et al [5] showed an effort to pause ratio (E:R) of 2:1, suggesting a less intermittent match than in the present study (E:R ratio for official combat = 1:1.5; E:R ratio for simulated combat = 1:1). In the present study, high-intensity actions to-rest differed significantly and generated a high-intensity effort-rest ratio of 1:11 for official and 1:7 for simulated matches. Bridge et al [8] and Santos et al [9] established similar results (E:R ratio 1:6) with taekwondo athletes during the World Championship and Olympic Games, respectively.

The higher [La] after official compared to simulated match indicates the higher glycolytic demand during the real combat karate condition compared to simulated ones. Consequently, this would suggest that the type of match (simulated vs official) influence the anaerobic energy provided by the glycolytic system. A similar value of [La] (7.7±1.9 mmol.l-1) was founded by Beneke et al [5] after karate combat simulation. Doria et al [28] reported that net [La] (i.e. highest post-competition lactate concentration minus resting values) was 7.5 ± 2.4 $mmol.l^{-1}$ after karate combat simulation. During the World Karate Championship, Arriaza [30] reported that mean [La] was 11.1 $mmol.l^{-1}$ [Range: 8.7 to 12.7 $mmol.l^{-1}$], similar to the present study's results. Obtaining higher lactate values within official compared to simulated combat, while the effort to pause-ratio is lower, suggests that even if fewer, the high-intensity actions are probably of much higher intensity in the official combat than during the simulated ones. These results suggest that it could be speculated that official combat is more anaerobic and that simulated combat could rely more on aerobic pathways when the combat is considered broadly.

Although rating of perceived exertion was higher during official ("somewhat hard") compared to simulated ("light") karate combat, there was a clear dissociation between lactate concentration and this variable. This can be due to the numerous physiological and psychological parameters that may influence effort's perception [31], especially the attention directed to the opponents' actions [10]. The perceived recovery scale was not significantly correlated to both the number of high-intensity actions and the total time of fighting activity. This result indicates that the values reported by the present study's athletes (adequately to moderately recovered) is sufficient for their regular performance as predicted ("expected similar performance") by the scale elaborated by the authors. Maybe lower values of perceived recovery scale would be correlated with lower-number of high-intensity actions or total-time of fighting activity. To the best of the authors' knowledge, the local rating of perceived exertion proposed by Nilsson et al [15] was used for the first time with high-level karate practitioners within the present study. The majority of karatekas perceived exertion to be the highest in the lower-limb muscles (i.e. quadriceps, hamstring, and triceps sural muscles) irrespective of the karate combat condition. Thus, although the athletes used more upper-limb attack techniques, the constant lower body displacements during the period of the combat seems to result in more fatigue located to these body parts. Additionally, as the karate techniques are powerful and fast movements interposed by long intervals, no significant fatigue was reported in the upper-limbs. These results can constitute valuable information towards programming training aiming to improve the endurance of the karateka's lower-limbs muscle groups. It is suggested that coaches could perform additional lower-limbs conditioning in order to delay the fatigue of these major lower-body muscle groups, allowing karatekas to perform combat with less fatigue sensation, which may possibly contribute to better performance. This has to be experimented by further studies.

CONCLUSION

High-level karatekas have the tendency to use more upper-limb attack techniques during official combat compared to simulated ones. This dominance can be due to the fact that there are greater chances to reach the target accurately when using upper-limb techniques compared to lower-limb ones. Longer time interval was found within official conditions compared to simulated matches. This difference can be explained by the fact that, during official matches, high-level karateka try to be engaged only in attack activities in which there are the highest chances of success, whereas during simulated conditions athletes are less concerned by the final result and, hence, by the chance of an attack to be successfully accorded. Blood lactate concentration was lower during simulated karate combat, suggesting that the type of match (simulated vs official) influences the anaerobic energy provided by the glycolytic system, and that combat simulation should include specific anaerobic tasks (e.g. extra technique actions in the interruption time) to better simulate the official match demand. The majority of karatekas' local rating of perceived exertion was higher in the lower-limb muscle groups irrespective of the karate combat conditions. These results can constitute relevant information for coaches towards optimizing karate's training program being directed for developing local endurance of lower-limbs muscle group as a determinant aspect during combat. This study presents some limitations including the relatively small sample size investigated. However, it was not possible to identify more athletes of such a level of practice. Future studies including a bigger sample size seems to be needed. Studies with female athletes, lower-level competitors and different age groups are also necessary.

ACKNOWLEDGMENTS

Authors would like to thank the Tunisian Karate Federation for granting access to the competitors during the competition and all karate athletes for their enthusiasm to the completion of this study. The present study was supported by the "Ministère de l'Enseignement Supérieur et de la recherche Scientifique", Tunisia

Conflict of interests: None

REFERENCES

[1] Koropanovski N, Berjan1 B, Predrag R, et al. Anthropometric and Physical Performance Profiles of Elite Karate Kumite and Kata Competitors. *J Human Kinetics* 2011;30:107-14.

[2] World Karate Federation (WKF). kata and kumite competition rules revision 8.0. Available at: http://www.britishkaratefederation.co.uk/uploads/wkf-competition-rules-version-8-0-2013.pdf. Access date: Jan 2013.

[3] Vos JA, Binkhorst RA. Velocity and force of some karate arm-movements. *Nature* 1966;211:89-90.

[4] Chaabène H, Hachana Y, Franchini E, et al. Physical and physiological profile of elite karate athletes. *Sports Med* 2012;42:829-43.

[5] Beneke R, Beyer T, Jachner C, et al. Energetics of karate kumite. *Eur J Appl Physiol* 2004;92:518-23.

[6] Iide K, Imamura H, Yoshimura Y, et al. Physiological responses of simulated karate sparring matches in young men and boys. *J Strength Cond Res* 2008;22:839-44.

[7] Matsushigue KA, Hartman K, Franchini E. Taekwondo: Physiological responses and match analysis. *J Strength Cond Res* 2009;23: 1112-7.

[8] Bridge CA, Jones MA, Drust B. The activity profile in international taekwondo competition is modulated by weight category. *Int J Sports Physiol Perform* 2011;6:344-57.

[9] Santos VG, Franchini E, Limasilva AE. Relationship between attack and skipping in taekwondo contests. *J Strength Cond Res* 2011; 25:1743-51.

[10] Bridge CA, Michelle AJ, Drust B. Physiological responses and perceived exertion during international taekwondo competition. *Int J Sports Physiol Perform* 2009;4:485-93.

[11] Artioli GG, Gualano B, Franchini E, et al. Physiological, performance, and nutritional profile of the Brazilian OlympicWushu (kung-fu) team. *J Strength Cond Res* 2009;23:20-5.

[12] Cappai1 I, Pierantozzi E, Tam E, et al. Physiological responses and match analysis of muay thai fighting. *Int J Perform Anal Sport* 2012;12:507-16.

[13] Davis P, Wittekind A, Beneke R. Amateur boxing: activity profile of winners and losers. *Int J Sports Physiol Perform* 2013;8:84-91.

[14] Milanez VF, Spiguel-Lima MC, Gobatto CA, et al. Correlates of session-rate of perceived exertion (RPE) in a karate training session. *Sci Sports* 2011;26:38-43.

[15] Nilson J, Csergö S, Gullstrand L, et al. Work-time profile, blood lactate concentration and rating of perceived exertion in the 1998 Greco-Roman wrestling World Championship. *J Sports Sci* 2002;20:939-45.

[16] Laurent CM, Green JM, Bishop PA, et al. A practical approach to monitoring recovery: development recovery status scale. *J Strength Cond Res* 2011;25:620-8.

[17] Koropanovski N, Jovanovic S. Model Characteristics of combat at elite male karate competitions. *Serb J Sports Sci* 2007;1:97-115.

[18] Tornello F, Capranica L, Chiodo S, et al. Time motion analysis of youth Olympic taekwondo combat. *J Strength Cond Res* 2013;27: 223-8.

[19] Goodwin ML, Harris JE, Hernandez A, et al. Blood lactate measurements and analysis during exercises : A guide for clinicinans. *J Diab Sci Technol* 2007;1:558-69.

[20] Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med* 1970;2:92-8.

[21] Pandolf B, Noble BJ. The effects of pedaling speed and resistance changes on perceived exertion for equivalent power outputs on the bicycle ergometer. *Med Sci Sports Exerc* 1973;5:132-6.

[22] Faul F, Erdfelder E. GPOWER: A Priori, Post-Hoc, and Compromise Power Analyses for MS-DOS (Computer Program). Bonn, FRG: Bonn University, Department of Psychology. 2004.

[23] Hopkins W. A Scale of magnitudes for effect statistics. Available at: http://www.sportsci.org/resource/stats/index.html. Accessed Jan, 2011.

[24] Koropanovski N, Dopsaj M, Jovanovic S. Characteristics of pointing actions of top male competitors in karate at world and european level. *Braz J biomotricity* 2008;2:241-51.

[25] Laird P, McLeod K. Notational analysis of scoring technique in competitive men's karate. *Int J Perform Anal Sport* 2009;9:171-87.

[26] Murdic R. Model of time parameter of attack in karate. Security, Belgrade 2001;1:91-116. [In Serbian]

[27] Jovanovic S. Karate 1 – Theoretic approach. Novi Sad: Sport's World. 1992. [In Serbian]

[28] Ruchlewicz T, Samitowski L, Sterkowicz S. Analiza techniki ataku w karate w świetle badań laboratoryjnych I obserwacji zawodow. Zeszyty Naukowe AWF Kraków 1984;36:182-94.

[29] Doria C, Veicsteinas A, Limouta E, et al. Energetics of karate (kata and kumite techniques) in top-level athletes. *Eur J Appl Physiol* 2009;107:603-10.

[30] Arriaza R. Karate. In: Kordi R, Maffulli N, Wroble RR, et al. Combat Sports Medicine. London: Springer-Verlag. 2009.

[31] Noble BJ, Robertson RJ. Perceived Exertion. Champaign, IL: *Human Kinetics*,1996.